Practitioner's Docket No.: 081468-0307087
Client Reference No.: P-0395.010-US

PATENT

OIPE JC17
MAR 30 2004
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: KLAUS SIMON et al. Confirmation No: 8896

Application No.: 10/724,402 Group No.: 1753

Filed: December 1, 2003 Examiner:

For: LITHOGRAPHIC APPARATUS AND DEVICE MANUFACTURING METHOD

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

SUBMISSION OF PRIORITY DOCUMENT

Attached please find the certified copy of the foreign application from which priority is claimed for this case:

Country	Application Number	Filing Date
EUROPE	02258278.7	November 29, 2002

Date: March 30, 2004

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Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

02258278.7

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

Anmeldung Nr:
Application no.: 02258278.7
Demande no:

Anmeldetag:
Date of filing: 29.11.02
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Lithographic apparatus and device manufacturing method

In Anspruch genommene Priorität(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

G03F/

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LI LU MC NL PT SE SK TR

Lithographic Apparatus and Device Manufacturing Method

The present invention relates to a lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- a patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate; and
- a projection system for projecting the patterned beam onto a target portion of the substrate, and particularly to such apparatus adapted to manufacture so-called "bio-chips".

The term "patterning means" as here employed should be broadly interpreted as referring to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate. Examples of such patterning means include: a mask, a programmable mirror array and a programmable LCD array.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens".

Further, the lithographic apparatus may be of a type having two or more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in US 5,969,441 and WO 98/40791, incorporated herein by reference.

In so-called "gene-chips" and other bio-chemical or fluidic MEMS (micro-electro-mechanical systems) it is necessary to attach specific biological or chemical compounds to specific areas on a substrate and in some cases it may be desirable to build up specific

DNA sequences on the substrate. To create a small device capable of performing a large number of tests, a correspondingly large number of different compounds must be attached in their respective areas, which may be of the order of 1-100μm in size. Existing photolithographic apparatus optimized for advanced semiconductor manufacture or manufacture on large area substrates, e.g. for flat panel displays, are not optimum for this type of work.

It is an object of the present invention to provide a lithographic projection apparatus suitable for manufacture of bio-chips and the like.

This and other objects are achieved according to the invention in a lithographic apparatus as specified in the opening paragraph, characterized in that:

said substrate table is provided with a fluid processing cell in fluid communication with a surface of a substrate held on said substrate, whereby a fluid can be brought into contact with said substrate so as to interact with said target portion.

The fluid processing cell provided on the substrate table enables a process to be carried out on the target portion of the substrate without removing the substrate from the apparatus. For example, the patterned irradiation of the substrate may selectively activate the surface thereof so that compounds, e.g. in solution, bond to the surface where it was activated but not elsewhere. A series of exposures and processes can be carried out with much greater throughput than if the substrate had to be removed from the apparatus between each exposure and process.

Preferably, the substrate table incorporates a plurality of fluid processing cells in fluid communication with respective areas of a substrate held on the substrate table, whereby one area of the substrate may be subjected to a process whilst target portions of another area are being exposed.

The fluid brought into contact with said substrate may comprise a gas or a liquid, e.g. a solution, a suspension or an emulsion. The interaction with the substrate may involve: a chemical reaction with the substrate surface or compounds thereon; removal of part of the substrate or compounds thereon; addition of compounds to the substrate; washing; or modification of the surface or atomic or electronic structure of the substrate or compounds adhered thereto. A fluid processing step may be carried out before an

exposure, e.g. to prime a layer of the substrate or deposit a radiation sensitive layer, during an exposure, e.g. to perform a reaction catalyzed by radiation, or after an exposure, e.g. to react selectively to parts of the target portion sensitized by the exposure radiation.

The fluid processing cell may be located in the substrate table underneath the substrate, i.e. on the opposite side than the projection system, for use with transparent substrates. Alternatively, the fluid processing cell may be above the substrate and formed with a transparent upper wall. If the fluid processing cell is above the substrate, the upper wall may be omitted for use with liquids not sensitive to air and gravity used to confine the liquid to the chamber.

The fluid processing cell is preferably integrated into the substrate table and substrates are loaded onto it in the machine. With this arrangement, known substrate handling devices and techniques may be used. The fluid processing cell may instead be separable from the substrate table whereby a substrate is attached to the fluid processing cell before the cell and substrate are together loaded onto the substrate table. Off-line mounting of the substrates allows an improved seal to the fluid processing cell to be formed.

In a preferred embodiment of the invention, the fluid processing cell is provided with a fluid inlet and fluid outlet and the height of the cell decreases from the inlet toward the outlet whereby capillary forces assist in removal of fluid from the cell.

According to a further aspect of the invention there is provided a device manufacturing method comprising the steps of:

- providing a substrate to a substrate table in a lithographic projection system;
- providing a projection beam of radiation using a radiation system;
- using patterning means to endow the projection beam with a pattern in its cross-section;
- projecting the patterned beam of radiation onto a target portion of the layer of radiation-sensitive material,

characterized by the further step of:

- exposing said target portion of the substrate to a fluid that interacts therewith to effect a process step while the substrate is held by said substrate holder.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of bio-chips, it should be explicitly

understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of chemical or biological sensor, "lab on a chip" bio-MEMS sensor or combination devices, including integrated circuits. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

In the present document, the terms "radiation" and "beam" are used to encompass all types of electromagnetic radiation, including ultraviolet radiation (*e.g.* with a wavelength of 365, 248, 193, 157 or 126 nm) and EUV (extreme ultra-violet radiation, *e.g.* having a wavelength in the range 5-20 nm), as well as particle beams, such as ion beams or electron beams.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which:

Figure 1 depicts a lithographic projection apparatus according to an embodiment of the invention;

Figure 2 depicts the fluid processing unit of the apparatus of Figure 1 in greater detail;

Figure 3 depicts the fluid management system of the apparatus of Figure 1;

Figure 4 is a cross-sectional view of the fluid processing cell of Figure 2; and

Figure 5 depicts an alternative fluid management system.

In the Figures, corresponding reference symbols indicate corresponding parts.

Embodiment 1

Figure 1 schematically depicts a lithographic projection apparatus according to a particular embodiment of the invention. The apparatus comprises:

- a radiation system IL for supplying a projection beam PB of radiation (*e.g.* UV radiation), which in this particular case also comprises a radiation source LA;

- a patterning means PM (e.g. a deformable micro-mirror array) for imparting a desired pattern to the projection beam.
- an object table (substrate table) provided with a substrate holder for holding a substrate W (*e.g.* a resist-coated silicon wafer), and connected to second positioning means (not shown) for accurately positioning the substrate with respect to item PL or PB;
- a projection system ("lens") PL (*e.g.* a refractive lens system) for imaging an irradiated portion of the patterning means onto a target portion (*e.g.* comprising one or more dies) of the substrate W.

As here depicted, the apparatus is of a reflective type (*e.g.* has a reflective patterning means). However, in general, it may also be of a transmissive type, for example (*e.g.* with a transmissive patterning means such as an LCD array)

The source LA (*e.g.* an Hg lamp) produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after having traversed conditioning means, such as a beam expander. The illuminator IL may include a filter FI to filter out undesirable wavelengths and a condenser CO. In this way, the beam PB impinging on the patterning means PM has a desired uniformity and intensity distribution in its cross-section.

It should be noted with regard to Figure 1 that the source LA may be within the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors); this latter scenario is often the case when the source LA is an excimer laser. An Hg lamp and liquid light guide as described in European Patent Application EP-A-1 256 848 may also be used. The current invention and claims encompass all of these scenarios.

Having been selectively reflected by the patterning means PM, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion of the substrate W. With the aid of the positioning means, the substrate table WT can be moved accurately, *e.g.* so as to position different target portions C in the path of the beam PB. In general, movement of the object table WT can be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not

explicitly depicted in Figure 1. The patterning means may just be connected to a short stroke actuator, or may be fixed.

The pattern to be imaged onto the substrate is provided to the patterning means which, in the case of a deformable micro-mirror array, sets its mirrors to selectively direct light into the projection system PL according to the pattern.

The depicted apparatus can be used in two different modes:

1. In step mode, the pattern displayed by the patterning means is kept essentially stationary, and an entire image is projected in one go (*i.e.* a single "flash") onto a target portion C. The substrate table WT is then shifted in the x and/or y directions so that a different target portion C can be irradiated by the beam PB;

2. In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the patterning means displays a scanning pattern with a speed v in a scanning direction; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (M may be from 1 to 1/10). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

In the embodiment of the invention, the substrate table WT additionally comprises a fluid processing unit FC (also referred to as a flowcell) by which a chemical process can be carried out on the substrate W - this is shown in more detail in Figure 2. After each exposure, a fluid flushes out the flowcell. For example, the fluid may contain one of the nitrogenous bases out of which DNA is build: **A**denine, **C**ytosine, **G**uanine or **T**hiamine. A desired DNA sequence can thus be assembled on the substrate. To remove the fluid, the flowcell is flushed out with dry Argon. During a process to build a DNA sequence, any exposure of the substrate to air is not allowed; air contains water vapor, which would disturb the DNA production process.

Figure 2 shows the fluid processing unit FC, which forms part of the substrate holder 10, and the substrate W, shown partly cut-away in the figure. The substrate W rests around its edges on walls 17, which bound vacuum area 13, which is evacuated to hold the substrate onto the substrate table. Pimples 16 support the substrate in a known manner. Within the vacuum area are several fluid chambers 11, formed by upstanding walls 15 of the same height as the walls 17 so that the substrate W closes the fluid chambers to form a

fluid processing cell. The height and flatness of the fluid chamber walls, the pimples and the outer walls 17 are determined so that the substrate W forms an adequate seal to the fluid chamber walls under the force exerted by the pressure differential between the atmosphere above and vacuum below, without unduly distorting the substrate. The fluid chambers are elongate, in this case stretching from near one side of the substrate to near the opposite side, and encompass several target portions C. They are preferably shallow to minimize fluid consumption. At one end a fluid inlet 12 (see Figure 4) is provided and at the other end there is a fluid outlet 14. To effect a desired process, fluid is provided to the fluid chamber via the inlet and removed via the outlet. A deliberate leak from the fluid chambers may be arranged to prevent contamination.

The vacuum system that generates the vacuum to hold the substrate down on the fluid processing unit also serves to remove any fluids that may leak from the fluid chambers, and any air that might enter the unit.

In this embodiment, the fluid processing unit is integrated into the substrate table WT and the substrate is loaded onto it using known devices, simplifying handling of the substrate. Alternatively, the fluid processing unit may be separable from the substrate table – the substrate is mounted onto the fluid processing unit outside the apparatus and then the unit and substrate are together loaded onto the substrate table. This arrangement may be advantageous in enabling a better seal between the substrate and fluid chambers to be achieved.

A fluid management system 20 is shown in Figure 3. The fluid processing unit is supplied by a single combined fluid/gas entry into the fluid processing unit. In this way the Argon flushing of the tubing towards the flowcell can be combined with the flushing of the flowcell itself. This minimizes the potential of 'non-flushable' cavities. To minimize the mass of the wafer table WT, the generation of heat on the table and the number of cables and hoses leading to the wafer table WT, which will need to be positioned with μm accuracy, the fluid management system is mostly located remotely of the table, with a fluid supply and a fluid extraction conduit leading to each fluid chamber 11 in the fluid processing unit FP.

The supplies of the fluid management system include a supply tank 21a,b,c, etc for each fluid to be used in the apparatus and a flushing gas tank, 22a. The flushing gas, e.g. Argon or Helium, is used to flush the fluid chambers 11 after each liquid process and

also to replace the fluids pumped out of the supply tanks 21a,b,c, etc.. One-way valves 27a-c are provided in the outlets from each of the liquid supply tanks 21a-c to prevent any dispensed fluid from returning to the tanks. The flushing gas tank 22a is equipped with a pressure regulator 22b, which brings the pressure down to a standard pressure, e.g. 12 bar. A pressure sensor 22c to monitor this is provided, as well as a valve 22d for sealing the container from the outside of the system.

To filter out any particles and condensate the flushing gas is directed through a filter unit 23a. The filter unit is integrated with a pressure regulator 23b and a pressure gauge 23c. The pressure regulator reduces the pressure further so that the flushing gas can safely be used for flushing the fluid chambers 11. As a last cleaning step, the flushing gas is directed through an active carbon filter 24, which captures particles larger than 0.003µm. A further, adjustable pressure regulation unit 25 is provided to control the pressure of the gas used to replace the fluids taken out of the fluid supply tanks 22a,b,c, etc..

To selectively connect the various supplies to the fluid processing unit FP, a series of 3/2 valves 26a-c are used these are electrically controlled and normally in a position to allow the flushing gas to flow through to the fluid processing unit FP. To deliver a liquid to the flow cell, the respective one of the 3/2 valves are opened to the fluid. A manual override to the electrical control may be provided.

2/2 valves 29, 32 in the supply and exhaust lines allows the fluid processing unit FP to be sealed if desired, e.g. if a process requires a liquid to remain in contact with the substrate for an extended period. A pressure gauge 29 monitors the pressure in the supply line to the fluid processing unit FP and can measure both liquid and gas pressures. On the output side of the fluid management system, a similar pressure gauge 30 monitors the pressure in the exhaust line from the fluid processing unit FP. A fluid detector 31 is also provided to detect whether or not fluid is flowing through the system, thereby enabling detection of an empty supply tank. The detector gives an electrical signal indicating the presence of fluids. Its exact form will depend on the fluids to be detected, e.g. hydrocarbons.

Mirroring the arrangement on the supply side, 3/2 valves 33a-c normally open to argon allow the fluids that have been flushed through the fluid processing unit to be separately collected in respective waste tanks 36a-c, to allow reuse or proper disposal. If separate collection is unnecessary, a single waste tank may be used and these valves may

be omitted. Argon used for flushing and air displaced form the waste tanks 36a-c is vented using a vacuum pump via a condenser 38 to collect any evaporated liquid. One way valves 37a-c are provided in the outlets of the waste tanks to prevent environmental air form entering the waste tanks.

In this embodiment, the fluids are sucked through the fluid processing unit FP by respective pumps 34a-c for the liquids and 35 for the flushing gas. This minimizes the chance of contamination. Alternatively, the fluids might be pushed through by a pump or pumps on the supply side or by gas pressure in the supply tanks.

Where the fluid processing unit has several fluid chambers, various arrangements are possible. Most simply, all the fluid chambers may be connected in parallel so that the same liquid is supplied to them all at the same time. It may however be desirable to be able to supply fluids to the chambers separately, e.g. to apply different processes to different ones of the target areas or to allow fluid processing to occur in parallel with exposures. In that case, a switching arrangement may be provided in the fluid processing unit to control delivery of fluids form a single supply conduit to selected ones of the fluid chambers. Alternatively, several fluid management systems, one for each fluid chamber, may be provided. This provides maximum flexibility at the cost of requiring additional supply and exhaust lines to be provided to the table.

Figure 4 is a cross-sectional view of a fluid chamber 11. As can be seen, the gap G1 between the floor 11a of the fluid chamber 11 and the substrate W near the fluid inlet is larger than the gap G2 near the outlet. Both gaps are of order 0.1mm or less. In this way, capillary forces between the liquid and the fluid chamber and substrate will draw the fluid towards the outlet, improving fluid removal after the fluid process. Preferably, the materials of the fluid chamber and substrate are chosen so that the fluid has high adhesive forces to them and low cohesive forces. For example, if the fluid is alcohol-based, glass may be used for the flowcell and substrate.

Figure 5 shows an alternative fluid management system to supply four separate fluid chambers within the fluid processing unit. Four fluids and a flushing gas are stored in supply tanks 41a-d and 42 respectively. As in the first fluid management system, the flushing gas container 42a is provided with a pressure regulator 42b which brings the pressure down to 12bar. A pressure gauge 42c and a valve 42d are also provided. The flushing gas supply is then provided to a filter and pressure regulator unit 43 comprising a

filter unit 43a with pressure regulator 43b and pressure gauge 43c which reduces the flushing gas pressure further so that it can be used for flushing the fluid chambers. The argon is also filtered by filter 44. To take up the space in the liquid containers 41a to 41d as fluid is pumped out, the flushing gas must be reduced in pressure further and this is done by pressure regulator 45 which includes an adjustable pressure regulator 45a and pressure gauge 45b. The flushing gas enters the fluid supply tanks 41a to 41d via one-way valves 47a to 47d. The fluid supplied from fluid supply tanks 41a to 41d exit via one-way valve 48a to 48d and distribution blocks 49a to 49d which provide the fluids to four multi-position valves 46a to 46d, one per fluid chamber on the fluid processing unit. Each multi-position valve allows independent selection between one of the four fluids and the flushing gas.

On the waste side, the waste line from each fluid chamber is provided with a two-position valve 50a to 50d enabling the fluid chamber to be shut, *e.g.* for a process requiring extended contact with the fluid. A fluid detector 51a to 51d is also provided in each waste line. The waste fluids are collected in waste container 52, though separate containers may alternatively be used. A pump 53 is used to suck flushing gas, and fluids, through the system.

Whilst specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the invention.

CLAIMS:

1. A lithographic projection apparatus comprising:

- a radiation system for supplying a projection beam of radiation;
- a patterning means serving to pattern the projection beam according to a desired pattern;
- a substrate table for holding a substrate; and
- a projection system for projecting the patterned beam onto a target portion of the substrate,

characterized in that:

said substrate table is provided with a fluid processing cell in fluid communication with a surface of a substrate held on said substrate, whereby a fluid can be brought into contact with said substrate so as to interact with said target portion.

2. Apparatus according to claim 1 wherein said substrate table is provided with a plurality of fluid processing cells in fluid communication with respective areas of a substrate held on the substrate table, whereby one area of the substrate may be subjected to a process whilst target portions of another area are being exposed.

3. Apparatus according to claim 1 or 2 wherein the or each fluid processing cell is located in the substrate table on the opposite side of the substrate than the projection system.

4. Apparatus according to claim 1 or 2 wherein the or each fluid processing cell is located on the same side of the substrate as the projection system.

5. Apparatus according to claim 4 wherein the or each fluid processing cell is formed with a transparent upper wall.

6. Apparatus according to claim 1, 2, 3, 4 or 5 wherein said fluid processing cell is integrated into the substrate table.

7. Apparatus according to claim 1, 2, 3, 4 or 5 wherein said fluid processing cell is separable from the substrate table whereby a substrate can attached to the fluid processing cell before the cell and substrate are together loaded onto the substrate table.

8. Apparatus according to any one of the preceding claims wherein the or each fluid processing cell is provided with a fluid inlet and fluid outlet and the height of the cell decreases from the inlet toward the outlet whereby capillary forces assist in removal of fluid from the cell.

9. A device manufacturing method comprising the steps of:

- providing a substrate to a substrate table in a lithographic projection system;
- providing a projection beam of radiation using a radiation system;
- using patterning means to endow the projection beam with a pattern in its cross-section;
- projecting the patterned beam of radiation onto a target portion of the layer of radiation-sensitive material,

characterized by:

- a fluid processing step of exposing said target portion of the substrate to a fluid that interacts therewith to effect a process step while the substrate is held by said substrate holder.

10. A method according to claim 9 wherein the interaction with the substrate comprises at least one of:

- a chemical reaction with the substrate surface or compounds thereon;
- removal of part of the substrate or compounds thereon;
- addition of compounds to the substrate; washing; and
- modification of the surface or atomic or electronic structure of the substrate or compounds adhered thereto.

11. A method according to claim 9 or 10 wherein said fluid processing step is carried out before an exposure.

12. A method according to claim 9 or 10 wherein said fluid processing step is carried out during an exposure.

13. A method according to claim 9 or 10 wherein said fluid processing step is carried out after an exposure.

ABSTRACT

Lithographic Apparatus and Device Manufacturing Method

A flowcell is provided on the substrate table so that a fluid can be brought into contact with exposed areas of the substrate to interact therewith. A series of exposures and chemical processes can thereby be carried out without removing the substrate from the substrate table.

Fig. 2

Fig. 1

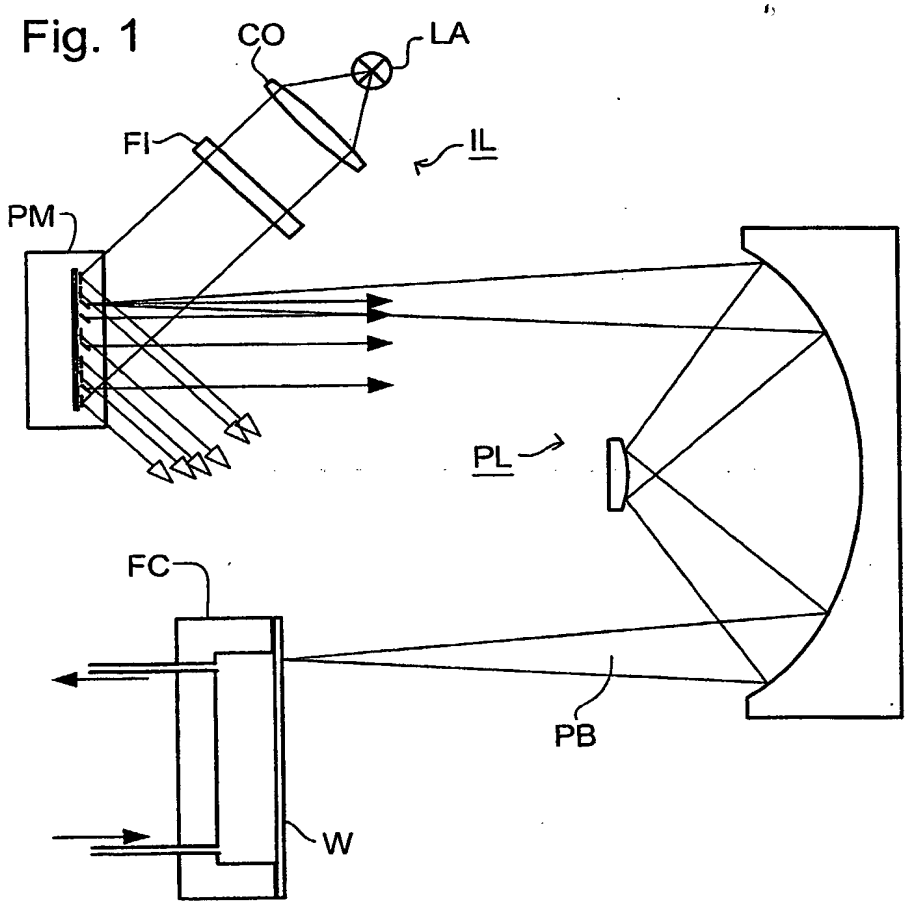

Fig. 2

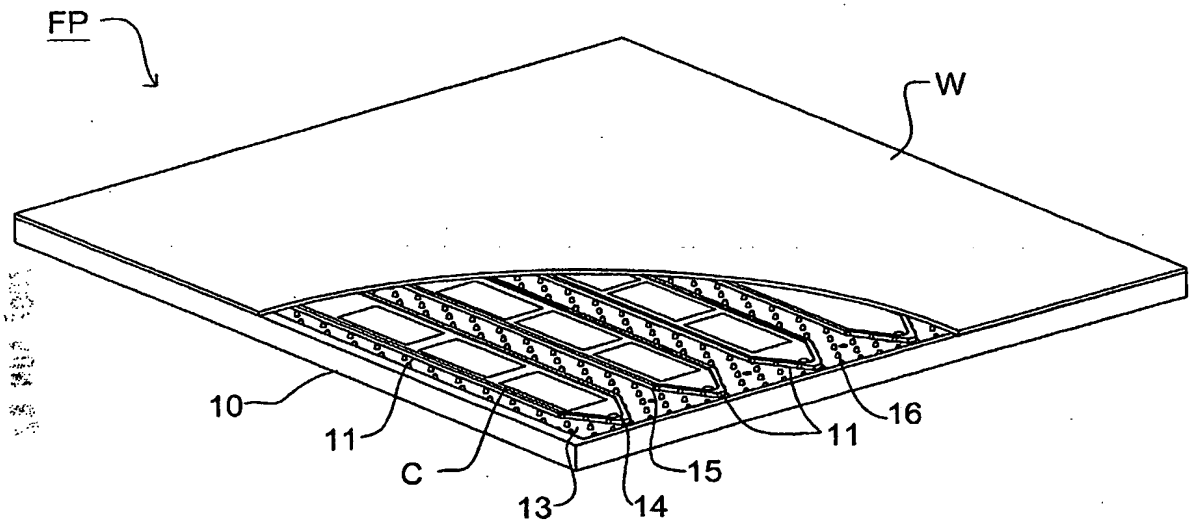

Fig. 3

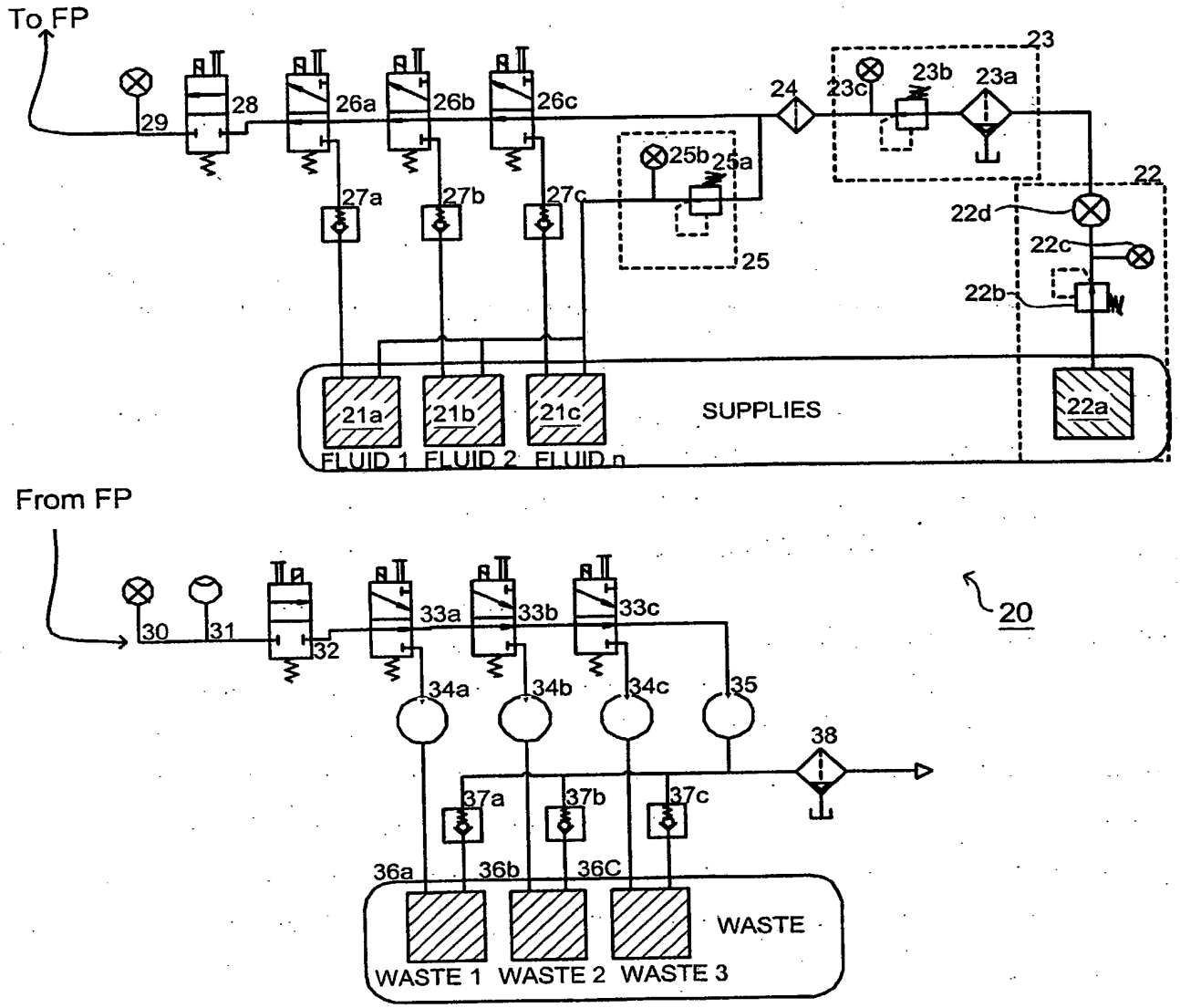

Fig. 4

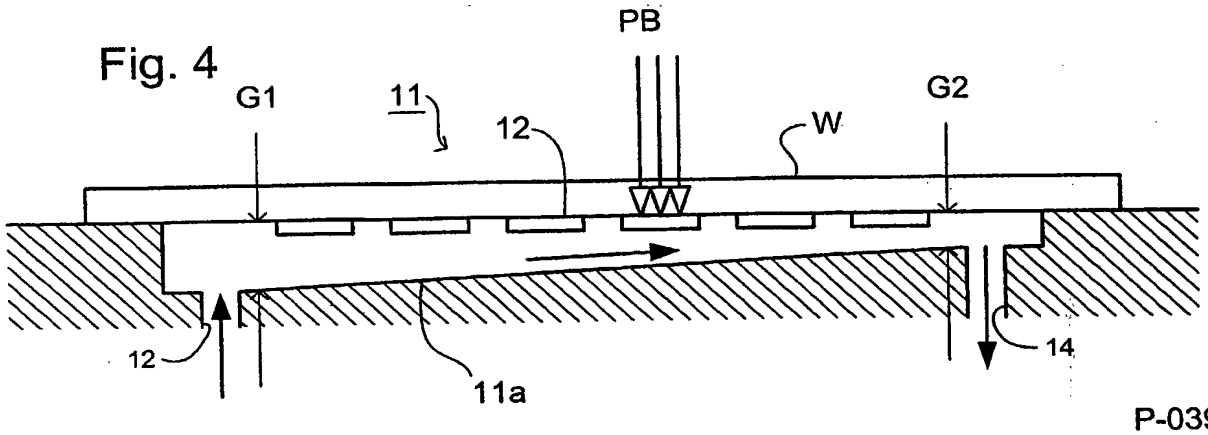

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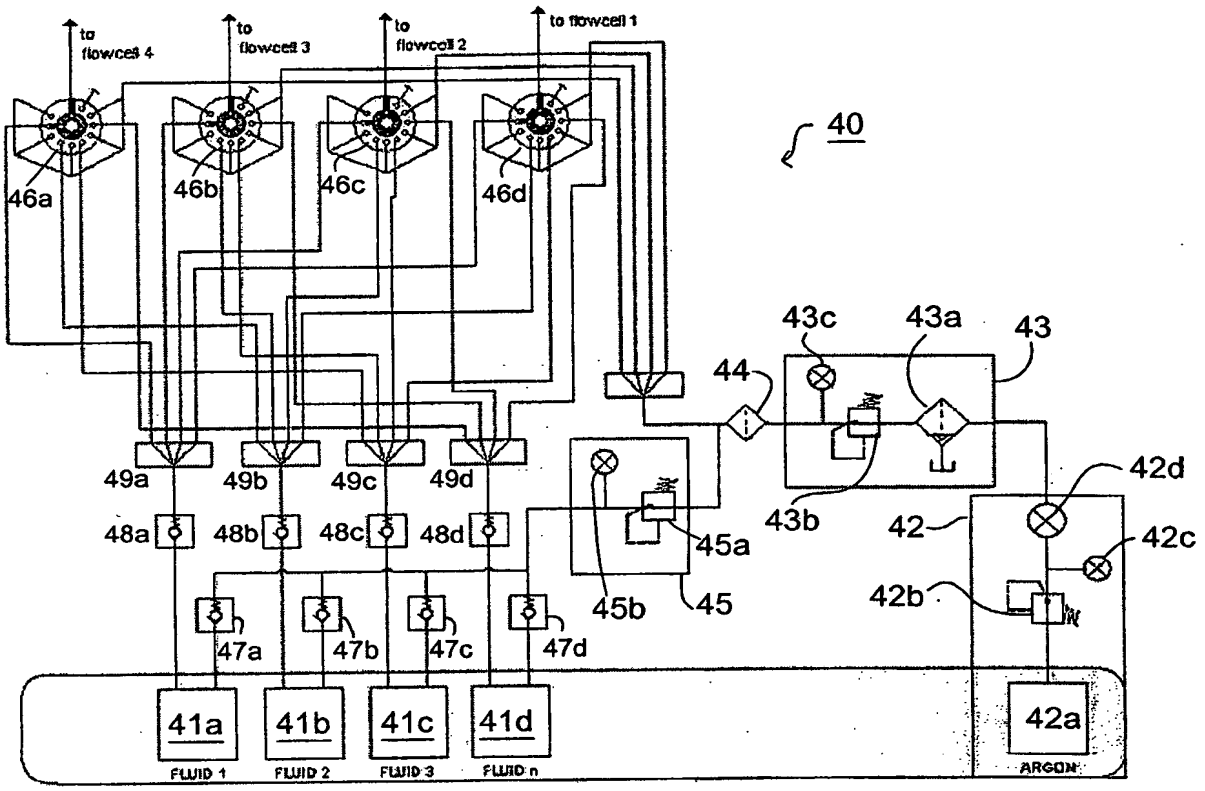
Fig. 5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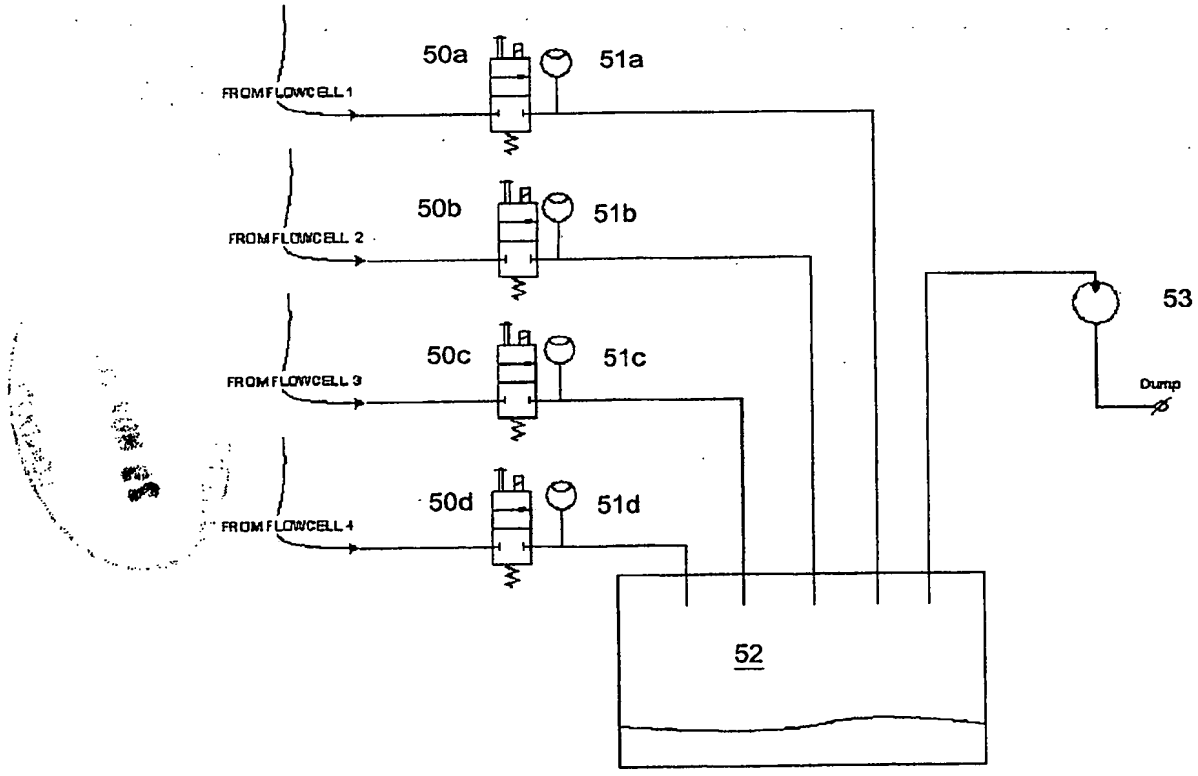
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P-0395